Generating Electric Current by Magnetic Field 1

Experiment with Electromagnetic Induction 1

~ Michael Faraday ~

NaRiKa Corporation

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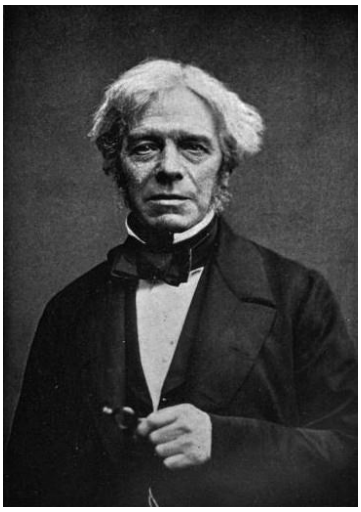
1. Learning Outcome

We can exemplify how magnetic field is generated by electric current through the experiments of Oersted, Ampere's Right-hand grip rule, and electromagnet as we did in the previous Units. In this Unit, we are going to examine, when electric current is carried through a coil, how magnetic field is generated and affect another adjacent coil. Insert an iron bar (core) into two coils that are not connected to each other. Then, connect a hand-held generator “Genecon V3” to one of the coils, and connect a Galvanometer to the other coil. By turning the handle of the Genecon V3 to pass an electric current through a coil, we will check how the Galvanometer connected to the other coil would be affected.

In case of using dry cell batteries or electric power-supply units, students can merely turn on a circuit and observe the electrical phenomena. However, they cannot only observe the experiment in operation, but also control it as they wish by using the hand-held generator Genecon V3, which helps students’ better understanding of experiments objectives through hands-on experience involving them.
Learning outcome of this Unit is for students to better understand the phenomena of experiment of M. Faraday through their hands-on experience.

2. Historical Background

Michael Faraday (1791 - 1867) was an English scientist who contributed to the fields of electromagnetism and electrochemistry. His main discoveries include electromagnetic induction, diamagnetism and electrolysis. It was by his research about magnetic field around a conductor carrying direct current, that Faraday established the basis for the concept of the electromagnetic field in physics.

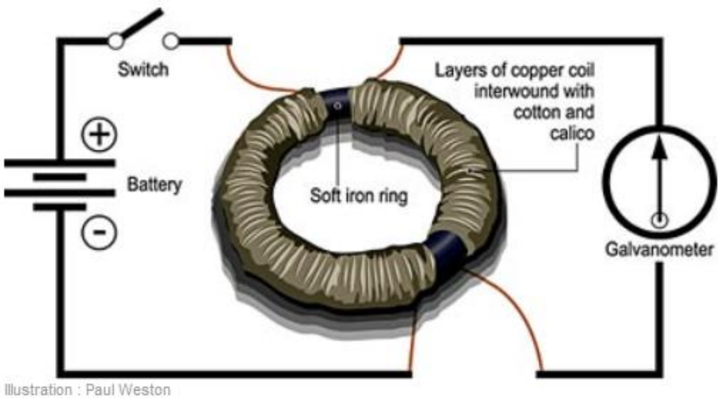

Michael Faraday
http://en.wikipedia.org/wiki/
File:Fara day-Millikan-Gale-1913.jpg

When Oersted discovered that electricity produces magnetism, Faraday wondered if magnetism could produce electricity. In 1831 he showed that it can. In Faraday's first experimental demonstration of electromagnetic induction, he wrapped two wires around opposite sides of an iron ring. He plugged one wire into a galvanometer and watched it as he connected the other wire to a battery. When the battery was connected, the needle of the galvanometer leaped into action, registering current in one coil. However, the effect quickly faded, and the needle soon detected no current, even though the battery was still connected.

Finally, years later, he found that if the battery is switched off and on repeatedly, the effect can be iterated over and over again. When the battery is connected, electrons flow along the copper wire of one coil round the windings around the ring. The effect of this is to induce magnetism in the ring. A magnetic field of excited electrons is created, producing an electrical current in the other coil, which is inside the magnetic field. This is one of Faraday's great discoveries: **Reciprocal (Mutual) Induction**: production of current in a coil only when changes of current occur (no change occurs during current carrying).

His major accomplishments:
- Electromagnetic induction
- Faraday effect
- Faraday constant
- Faraday's law of electrolysis
- Electric line of force
- Faraday gauge
- Faraday cup

Nowadays **Reciprocal (Mutual) Induction's** Definition: It is the phenomenon in which a change of current in one coil causes an induced emf (electromagnetic field) in another coil placed near to the first coil. The coil in which current is changed is called primary coil and the coil in which emf is induced is called secondary coil. Consider two coils placed near each other. When current is passed through the primary coil, magnetic flux is produced. This magnetic flux is also linked with the secondary coil. If the current is changed by varying the resistance in the primary circuit, the magnetic flux also changes. As this changing flux is linked with the secondary coil, it induces an emf in it. This phenomenon of inducing emf in a coil by changing current in another coil is known as mutual inductance.



3. Introduction of Equipment for Experiments

[1] Genecon V3:

Genecon V3 is a product name of the hand-held power generator manufactured by Narika Corporation. Up to 3V DC electricity can be generated just by turning the handle, hence the user realizes how he/she is generating electric power in person. Since Genecon V3 generates only up to 3V, it highly unlikely damage accessories used for experiment at schools like miniature bulbs, LED lamps, electric musical (melody) boxes, and others. Also, it replaces dry cell batteries used for experiment like lighting miniature bulbs/LEDs, electrically heated wire, or others.

Mechanism of Genecon V3 is quite simple, consisting of the motor inside for generating power, which should leave almost no room for students to misunderstand the relationship/function of internal motor, gears, shafts and handle due to its perfect visibility through the transplant body. For teachers, Genecon V3 significantly helps their explanation to students regarding the fact that motor and generator are identical.

Genecon V3 (Narika B10-2634)

[2] Galvanometer GM-6000:

Galvanometer is equipment used to detect current with sensitivity of approx. 2.5 μA and full scale indicating ±50 μA. Being equipped with amplifier (approx. 1000x), this is a special extremely sensitive Galvanometer which can detect very small amount of electric current.

For instance, it is able to detect small amount of electric current generated by the electromagnetic induction that happens when a magnet is brought near a straight wire. Also, it is still able to detect very small amount of electric current generated by the electromagnetic induction that happens when a long wire interacts with the “magnetic field lines of the earth” instead of a magnet.

Galvanometer GM-6000

(Narika A05-7120)

- Voltage sensitivity: approx. 1.6×10^{-4} V/mm
- Current sensitivity: approx. 2.5×10^{-6} A/mm, Full scale indicating ±50 μA (center zero)
- Amplification degree: Differential amplification, Amplification factor 60dB

4. Faraday's Experiment with Electromagnetic Induction ~ Michael Faraday ~

Years after A. M. Ampere discovered the Ampere' law (right-hand rule) in 1820, by which basic theory of electricity and magnetism was proposed, William Sturgeon and Joseph Henry discovered and invented electromagnet in 1828.

Michael Faraday has, derived from the Oersted discovery of fact that electric current makes magnetic field, started to think that magnetic field can make electricity. He had been conducting research related to magnetic field created around electrical conductor when direct electric current was flowing.

Faraday's Apparatus (Narika)

Faraday created two coils by wrapping nichrome wires on an iron ring. When he supplied electric current to one of the coils, he found that the current flow instantaneously in the other coil, as well (in 1831).

5. Experiment with Electromagnetic Induction

1. Purpose of the Experiment:

To confirm Faraday's experiment with electromagnetic induction.
By using two coils and iron core connected with Genecon V3 as an electric power source, verification of the current using a Galvanometer.

2. What to prepare:

*Genecon V3: 1 pc (Narika B10-2634)
*Coils (400 turns) & Steel core: 2 pcs (Narika B10-2631-05)
*Galvanometer GM-6000: 1 pc (Narika A05-7120)
*Cable with clips (red and black): 1 pc (Narika B10-6503)

Genecon V3 (Narika B10-2634)

Galvanometer GM-6000

(Narika A05-7120)

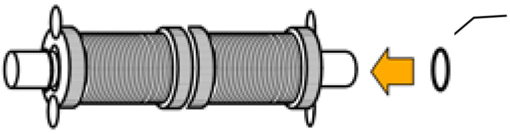
Coils

(Narika B10-2631-05)

3. Procedure of the Experiment:

1) Insert one iron core into two coils in series.

2) In order to prevent the coils would not fall off from the iron core, set two rubber band at either end of the iron core (as shown on the drawing below).



Setting rubber bands makes your experiment much easier.

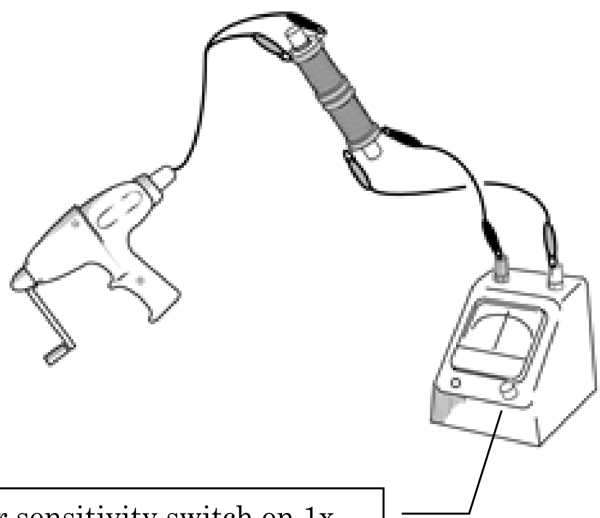
3) Set the Galvanometer sensitivity switch on x1 (Do not set it to 1000x).

4) Connect terminals of one coil, through cables with clips, to Galvanometer GM-6000.

5) Connect terminals of the other coil, through a cable with clips, to Genecon V3.

6) Start turning the handle of Genecon V3.

7) Observe the needle deflection of Galvanometer and write it down.



Set the Galvanometer sensitivity switch on 1x. Setting it on 1000x might damage the meter.

6. Summary of the Experiment

1. How does the needle of Galvanometer deflect when you turn the handle of Genecon V3?

Acceptable answers for this question would be: 1) Maximal deflection of the needle is shown at the beginning of turning the handle, 2) Deflection of the needle becomes smaller during turning handle, and/or 3) Deflection of the needle is synchronized with the timing of turning handle, rather than such a simple answer as "The needle of Galvanometer deflects when turning handle of Genecon V3."

2. How does the needle of Galvanometer deflect when you turn the Genecon V3 handle alternatively clockwise and anti-clockwise?

Acceptable answers for this question would be: "Maximal deflection of the needle is shown every time we change the direction of turning the handle." in addition to such an answer as "the direction of the needle deflection changes when we change the direction of turning the handle from clockwise to anti-clockwise and vice versa".

3. Even though the two coils are not connected via conducting wire, when you turn the handle of Genecon V3, the needle of Galvanometer deflects, which means electricity flows through the coils. Think about possible reasons why does electricity flow and write it below.

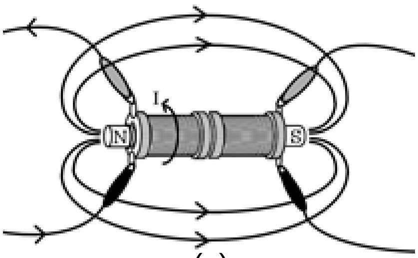
When electric current flows through Coil 1 by using Genecon V3, North and South poles occur on the iron core inserted orthogonal to the Coil 1 (electromagnet phenomenon). Then another magnet force is newly generated (orthogonal to the Coil 2) on the (edge of) iron core inserted into Coil 2, as if it counteracts the magnetic force generated at Coil 1.

4. When iron core is inserted into two of the isolated coils, if we supply electric current to one coil, then electric current is induced to the other coil. Describe below by drawing this phenomenon with flow of electric current and magnetic field.

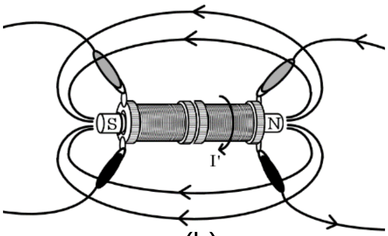
The phenomenon of "Reciprocal (Mutual) Induction" is interpreted to occur mainly based on following two phenomena; (a) North and South poles occur on the iron core inserted orthogonal to the Coil 1 when electric current flows through Coil 1 by using Genecon V3, (b) North pole occurs at the South pole mentioned in (a) and the South pole occurs at the North pole mentioned in (b), counteracting each other respectively, which induce the electric current in the Coil 2. Since (a) and (b) occur almost concurrently, the whole phenomena can be figured as shown in (c).

In other words, as seen in each of the cases above 1, 2 and 3, electric current is generated only when change in magnetic force lines occurs. Otherwise, Reciprocal (Mutual) Induction does not happen.

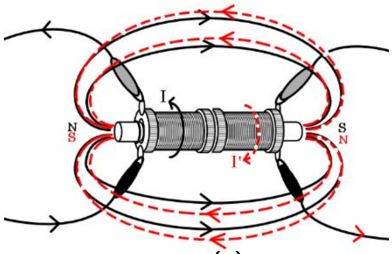
Meanwhile, needle deflection of Galvanometer is observed due to the “deflection of the magnetic force lines” in accordance with the pulsating electricity flow generated by Genecon V3. On the other hand, if dry cell batteries or power supply unit are used instead of Genecon V3, needle deflection of the Galvanometer would not appear.



(a)



(b)



(c)